Airborne remote sensing of clouds and precipitation using Ka- and W-band

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and many others …

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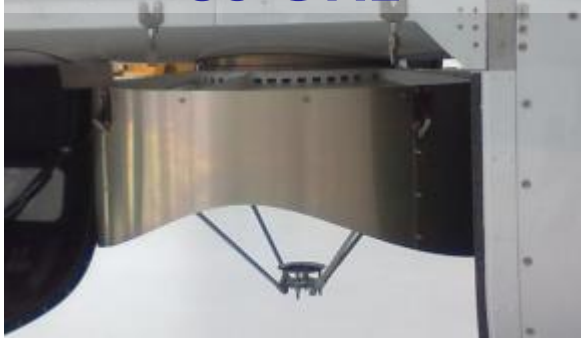
HAMP – HALO Microwave Package / NARVAL configuration

- METEK MIRA-35 cloud radar
- RPG microwave radiometers
- WALES / HRSL water vapour lidar
- drop sondes
- HALO-SR
- DOAS

Microwave radiometer
90/119 22/58 183 GHz

WALES / HRSL

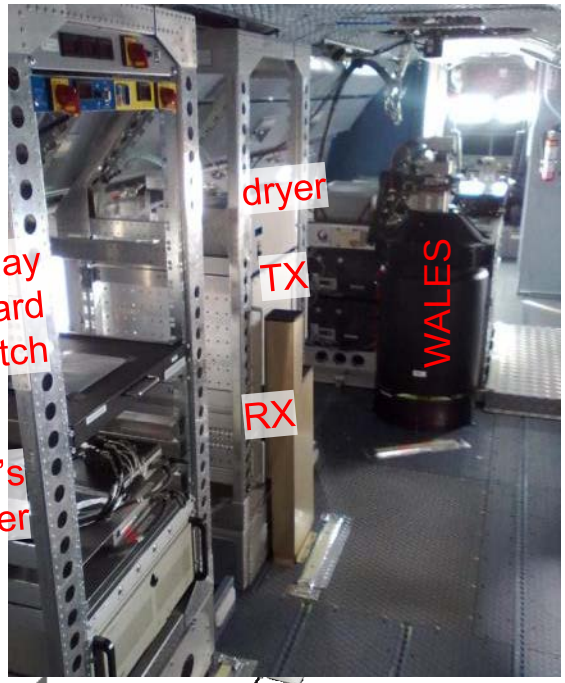
Cloud radar
35 GHz

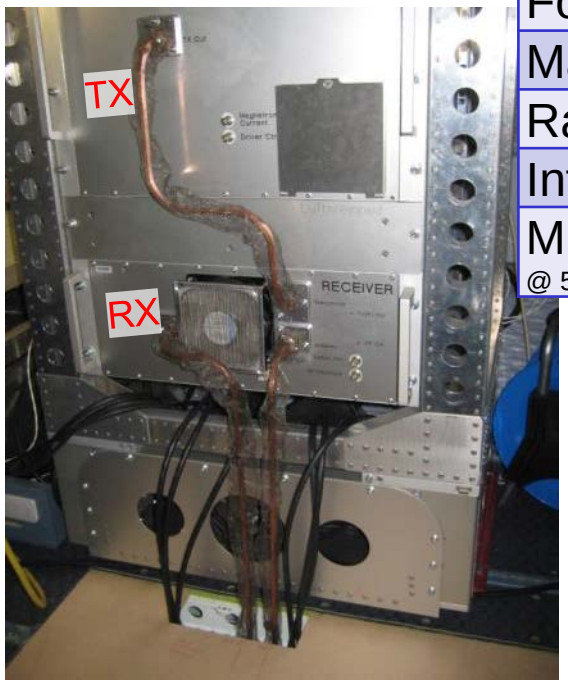


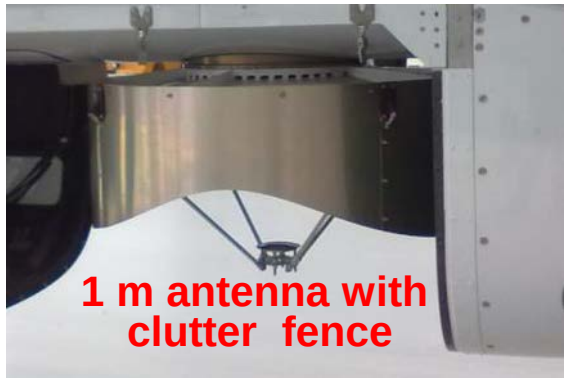
HALO Cloud Radar

- Modified MIRA-35 for aircraft use
  - EMC compatibility
  - mitigation of electromagnetic radiation in cabin or to avionics
  - adapted clutter fence
- any technical modification requires paper work, costs, delays, …

Characteristics MIRA-35	
Frequency	35.2 GHz
Wavelength	8 mm
Tx power	30 kW
Pulse length	0.2 µs
PRF	5 kHz
Antenna dia.	1 m
Beam width	0.6°
Footprint @ 13km	136 m
Max. range	15 km
Range resolution	30 m
Integration time	1 s
Min. detect. signal @ 5km, 1 s integration	-38 dBz



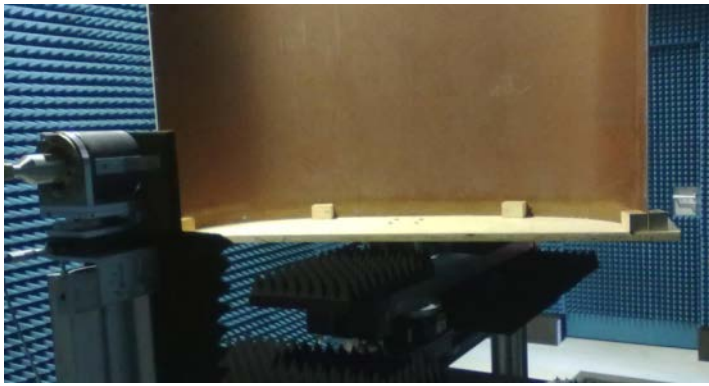


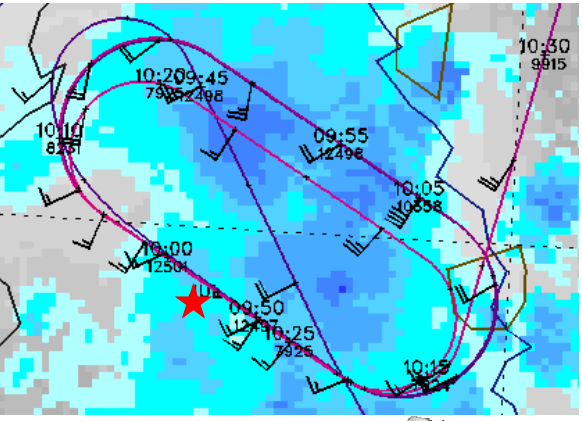


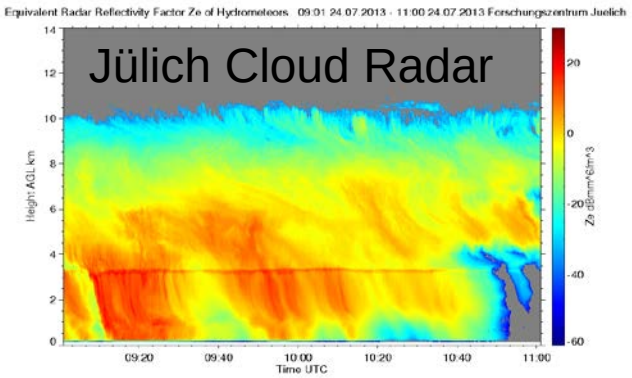
Calibration Issues

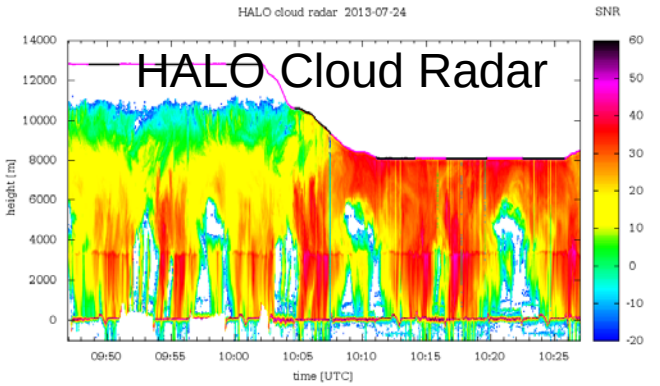
Radar calibration

- Manufacturer calibration for trailer version
- Rearrangement of radar for aircraft usage (avoidance of leakages)
- Longer and bended wave guides (0.7 dB/m one-way)
- Losses by radome plate (1.2 dB one-way)
- Comparison during flights over ground-based MIRA-35, Cloudsat underpass, joint flight HALO – French Falcon (2013), or calibration using sea-scatter









NARVAL Next-generation Aircraft Remote Sensing for Validation Studies

NARVAL-South

North Atlantic trade wind clouds

PI: B. Stevens, F. Ament

10 – 21 December 2013

- 8 flights over tropical and subtropical Atlantic
- 7 A-train underpasses
- 75 drop-sondes released
- joined flight with French RASTA

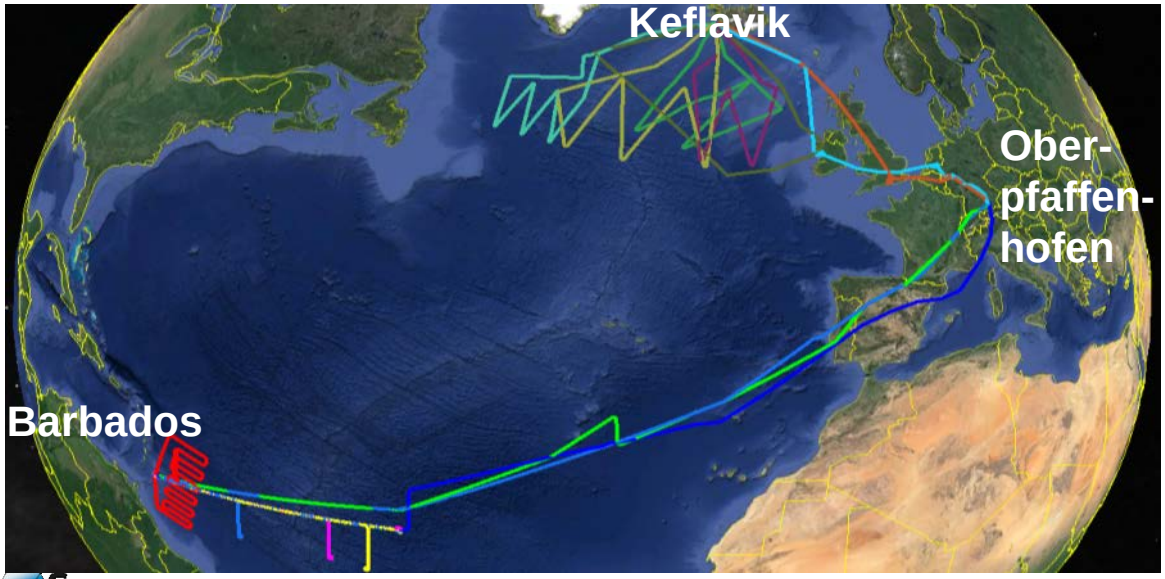
NARVAL-North

post-frontal extra-tropics systems

PI: C. Klepp, S. Bakan

7 – 21 January 2014

- 5 flights over North Atlantic
- 2 transfer flights with 5 super-site overpasses
- 4 A-train underpasses
- 42 drop-sondes released



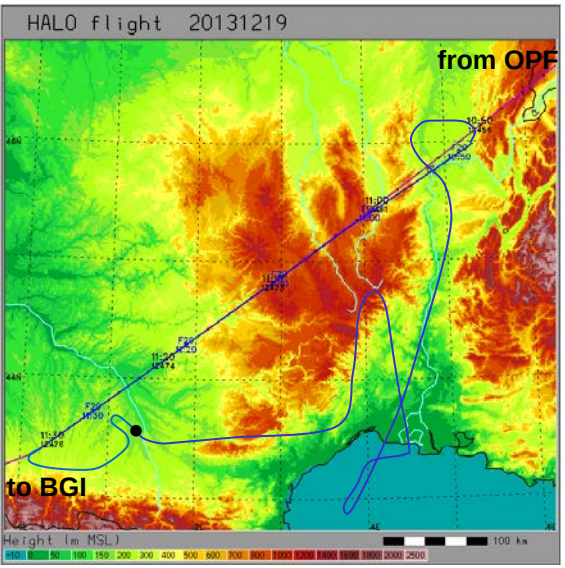
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

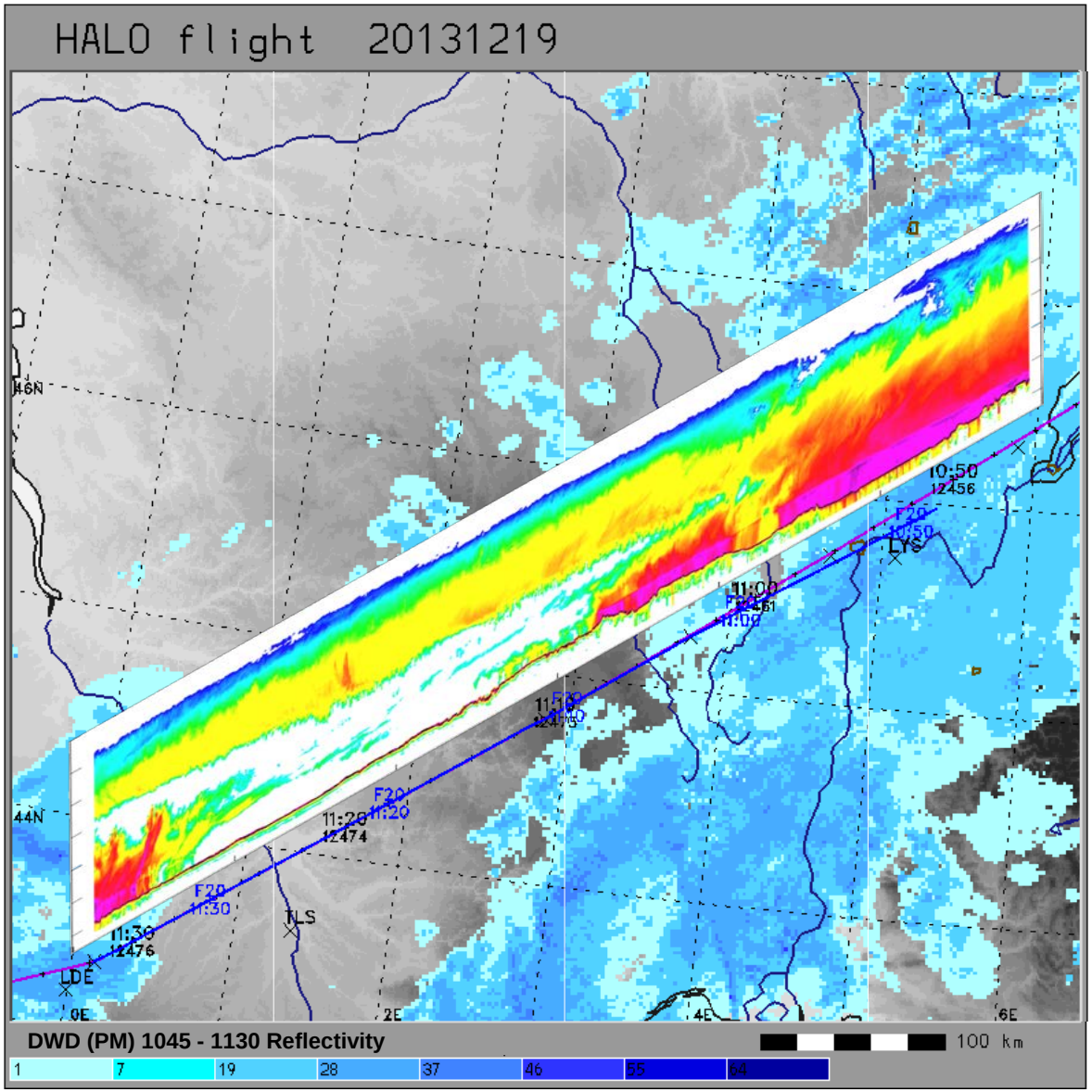
Joint flight

during NARVAL (19 Dec. 2013)

between

Lyon and Tarbes





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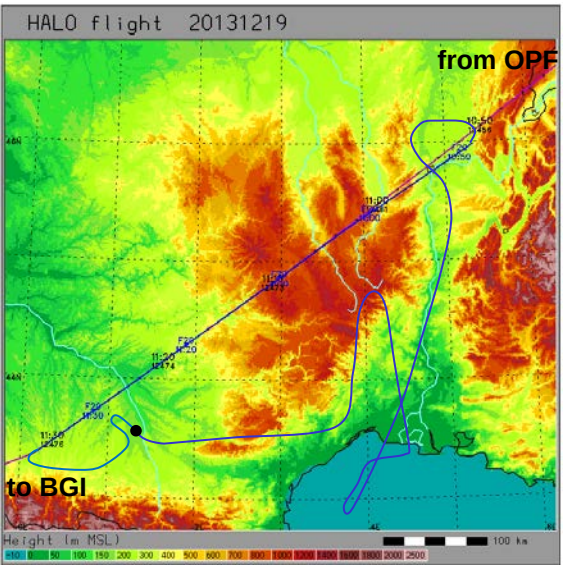


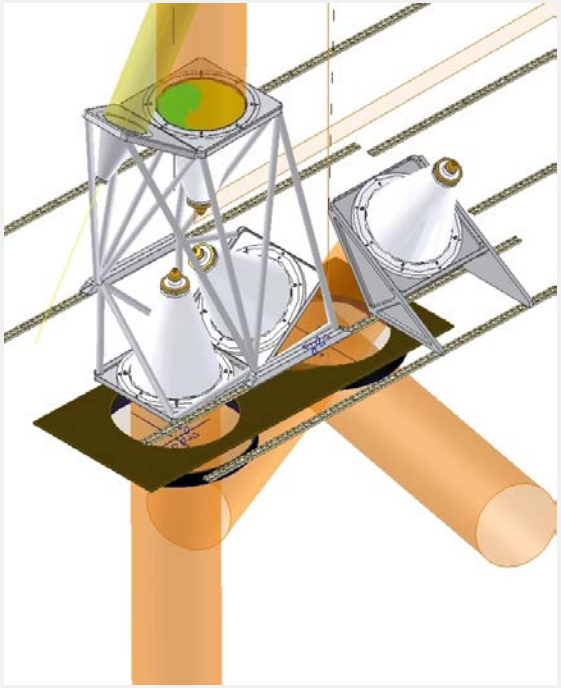
RASTA

(Radar aéroporté et sol de télédétection des propriétés nuageuses)

on-board French research aircraft Falcon F20

5 beam configuration for wind field estimation

Frequency	95.04 GHz
Tx power	1.8 kW
Pulse length	0.4 µs
Max. range	18 km
Antenna diam.	0.3 m
Beam width	0.7°
Min. det. sig. @ 1 km 1 s integration	-23 dBz



HALO Cloud Radar (Ka-band) – French RASTA (W-band)

Joint flight

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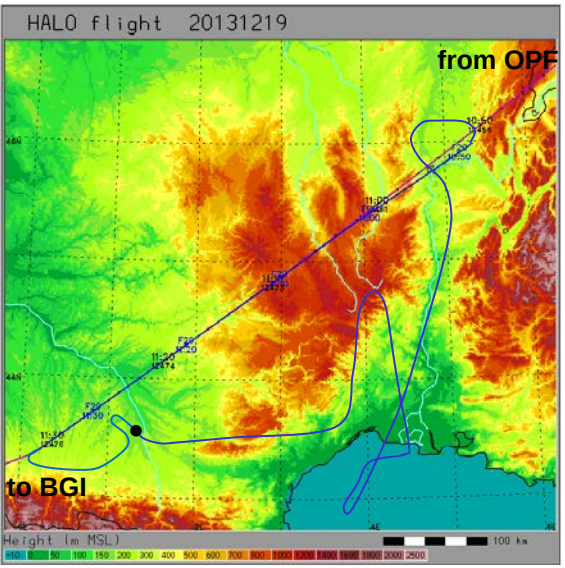
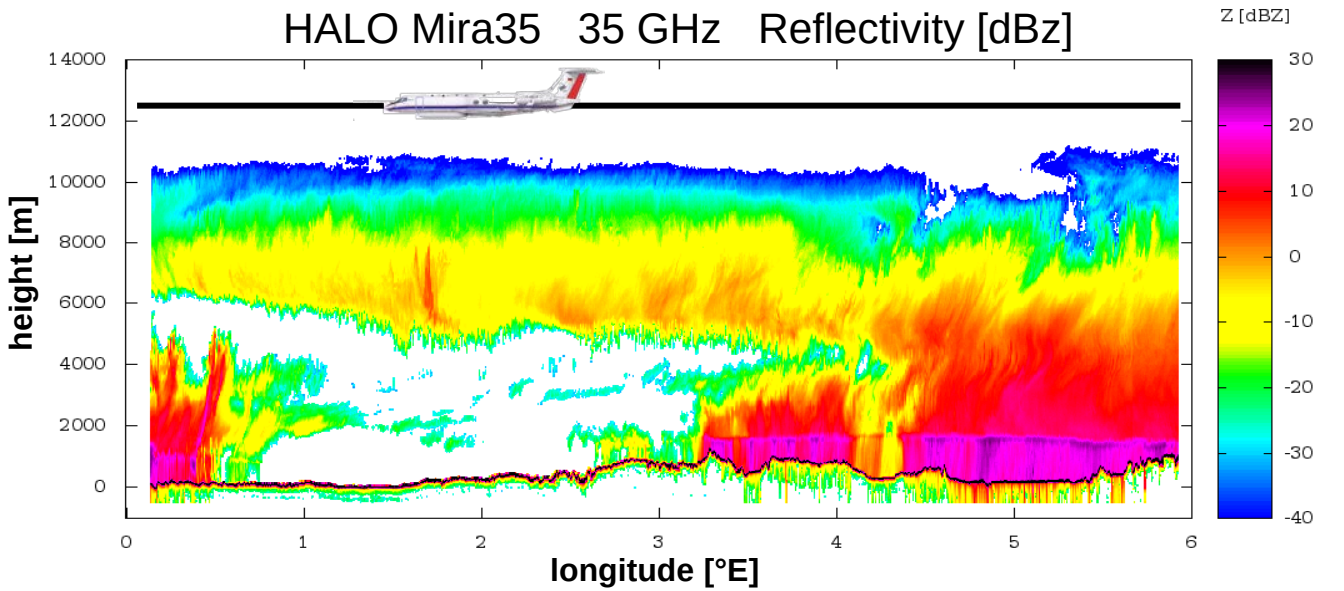
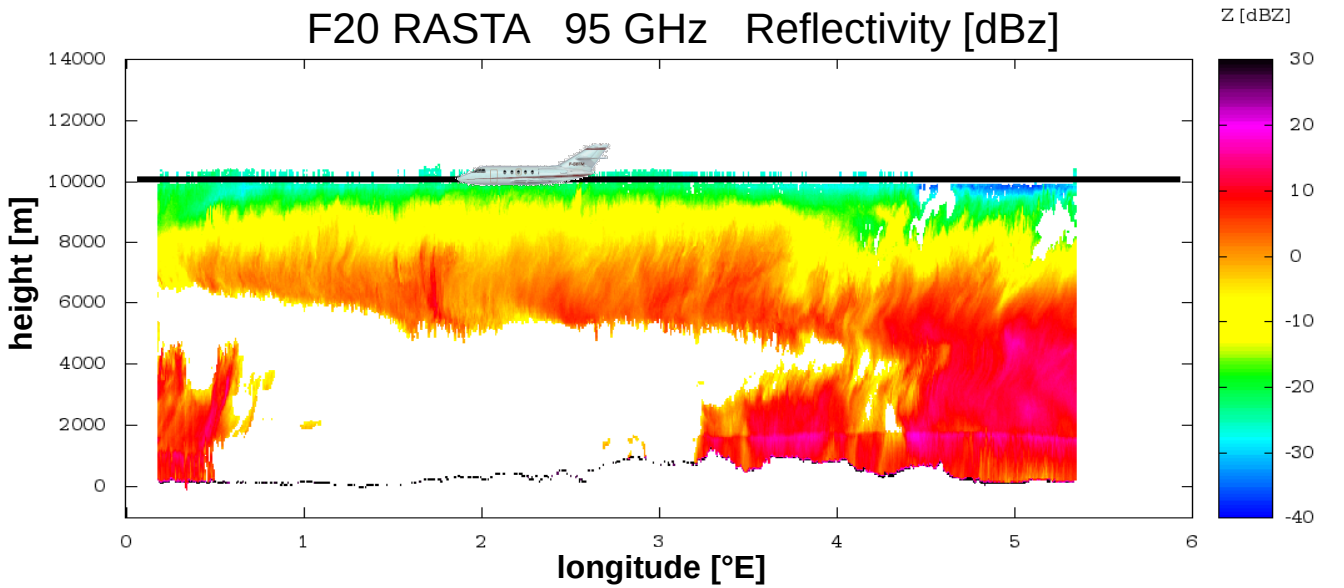
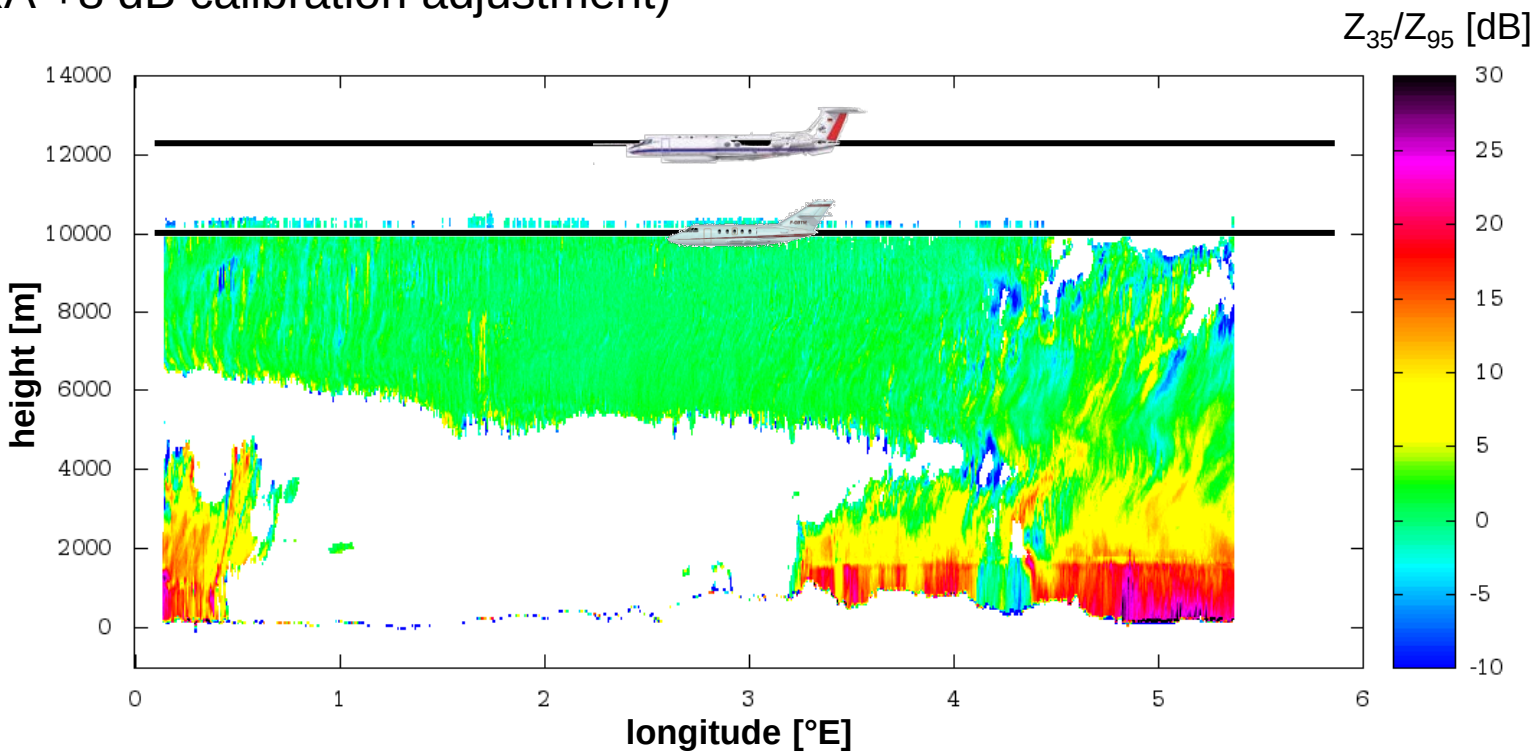






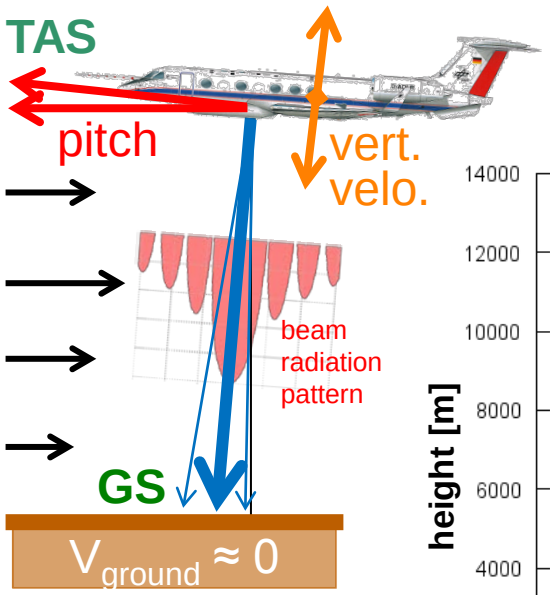
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

Dual-Frequency Ratio MIRA (35 GHz) – RASTA (95 GHz) reflectivity
(MIRA +8 dB calibration adjustment)

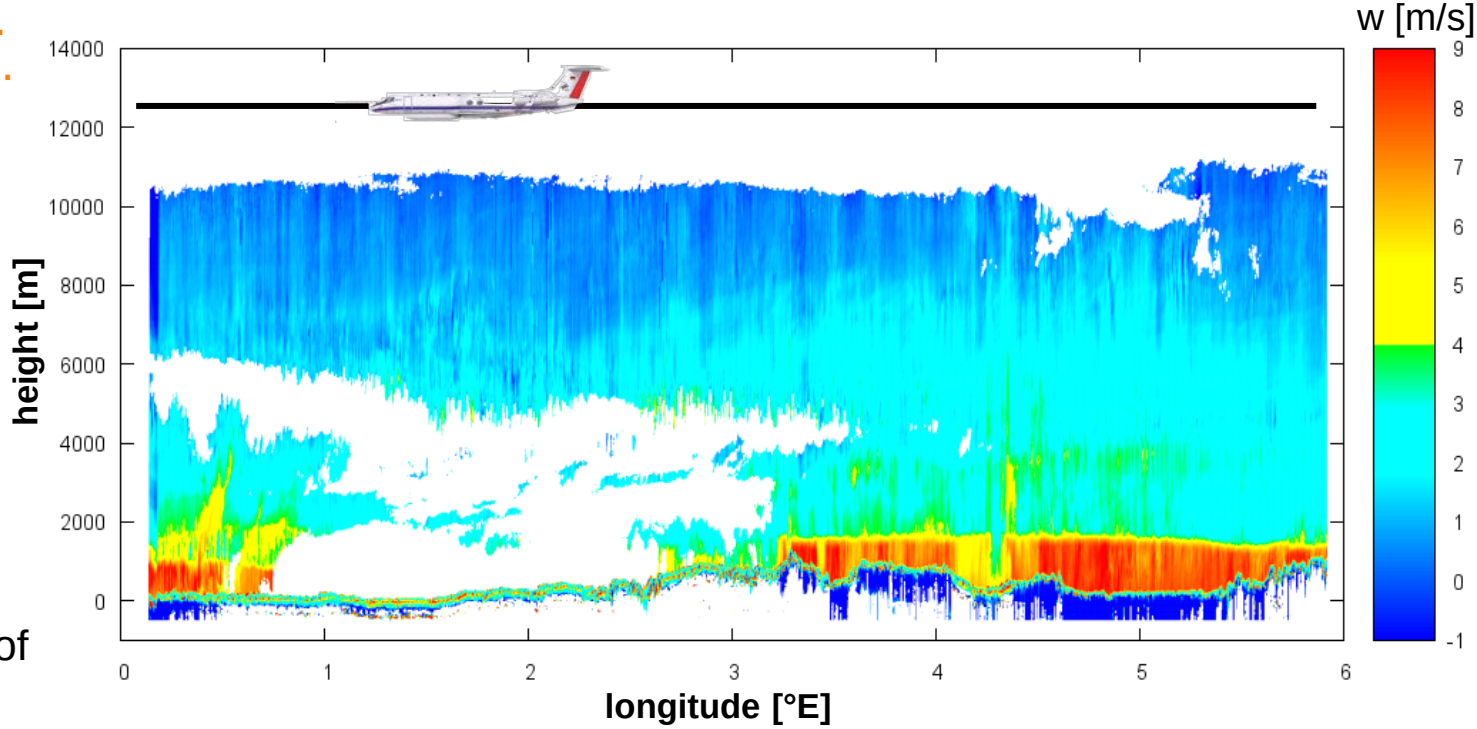


advection correction necessary (currently still ongoing)
wind at z = 5 km SW 30 kt
10 km SW 70 kt
12 km SW 50 kt

HALO Cloud Radar (Ka-band) – French RASTA (W-band)



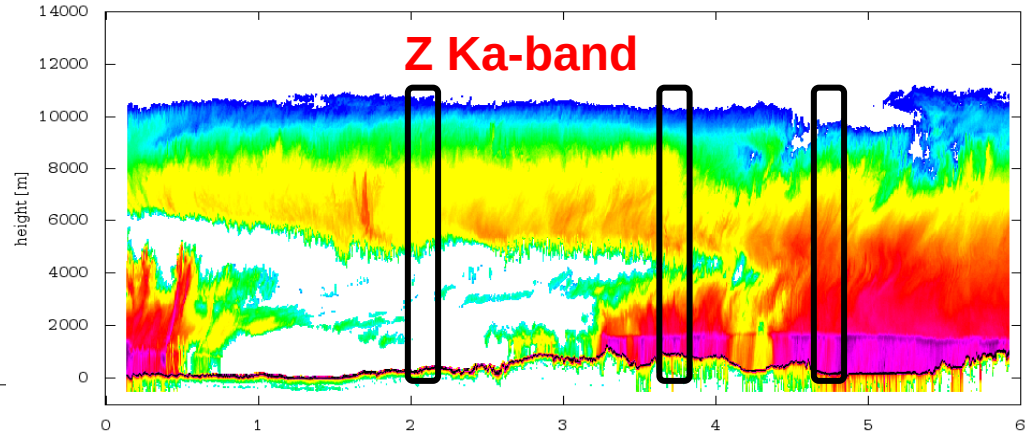
Ka-band Doppler velocity
(corrected by pitch, TAS, and vertical aircraft motion)

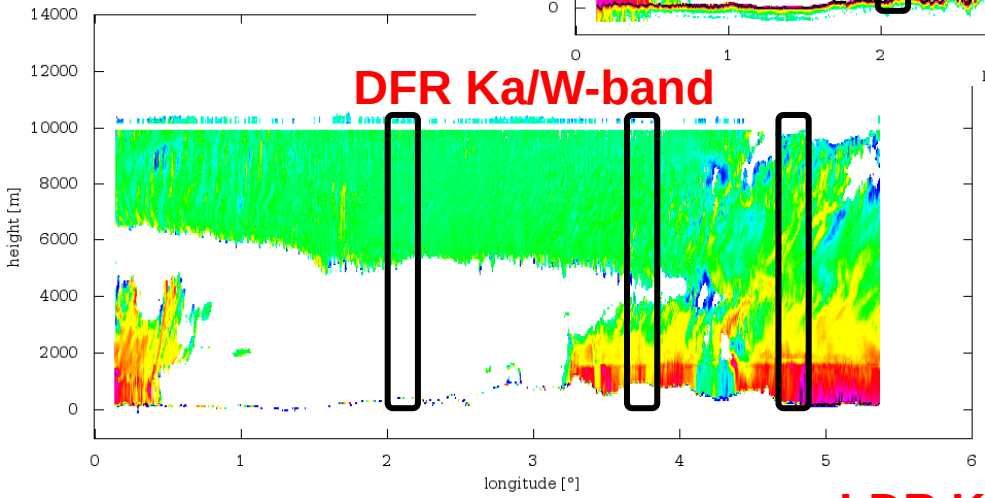


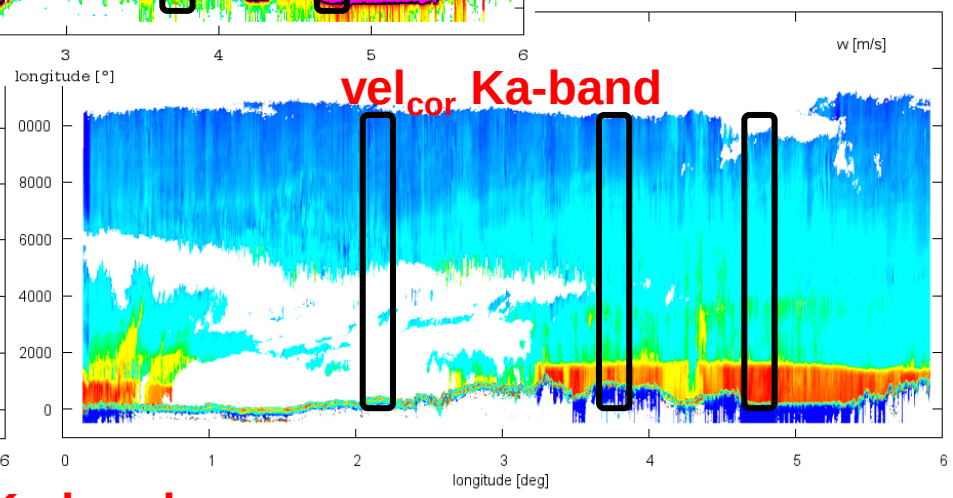
remaining contribution of vertical gradient of horizontal wind

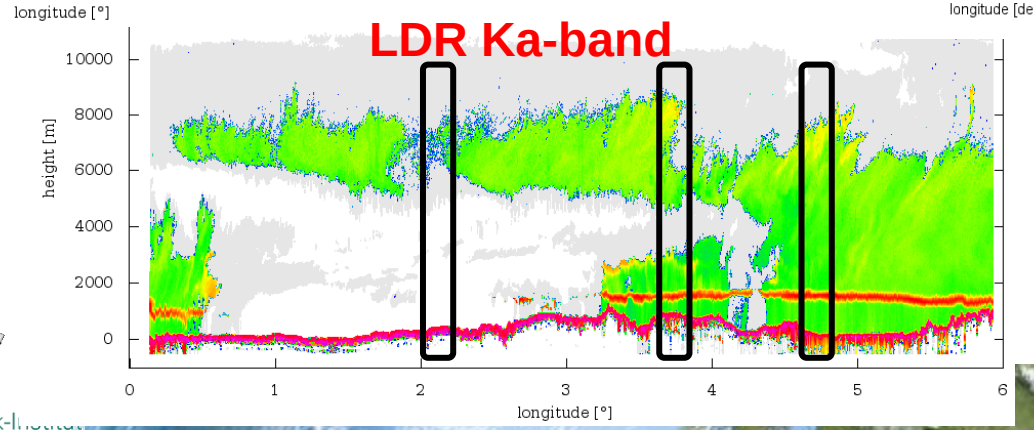
at z = 5 km SW 30 kt
10 km SW 70 kt
12 km SW 50 kt

HALO Cloud Radar (Ka-band) – French RASTA (W-band)



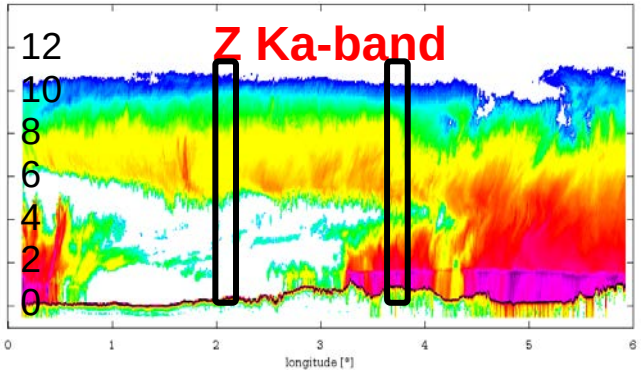




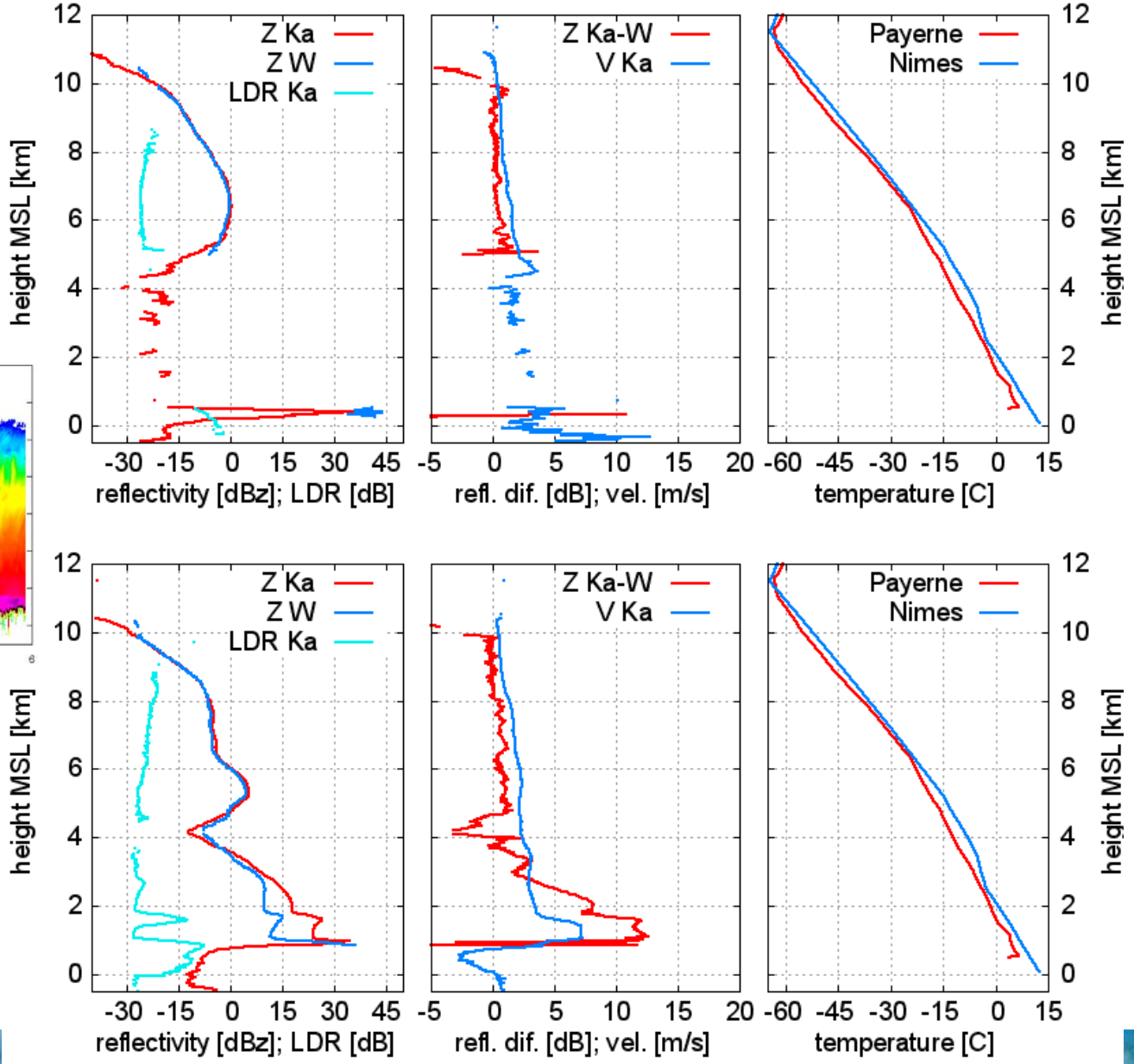


HALO Cloud Radar (Ka-band) – French RASTA (W-band)

2.00 E – 2.15 E

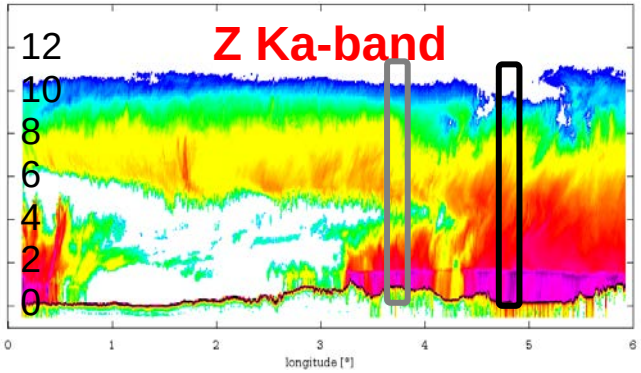


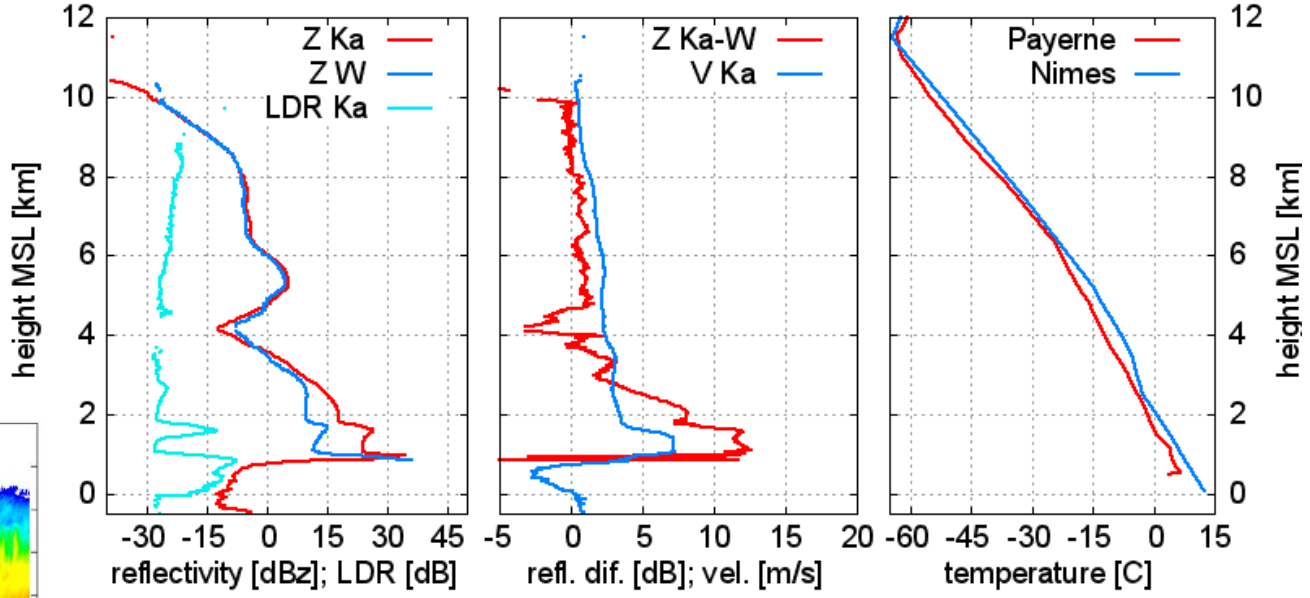
3.70 E – 3.85 E



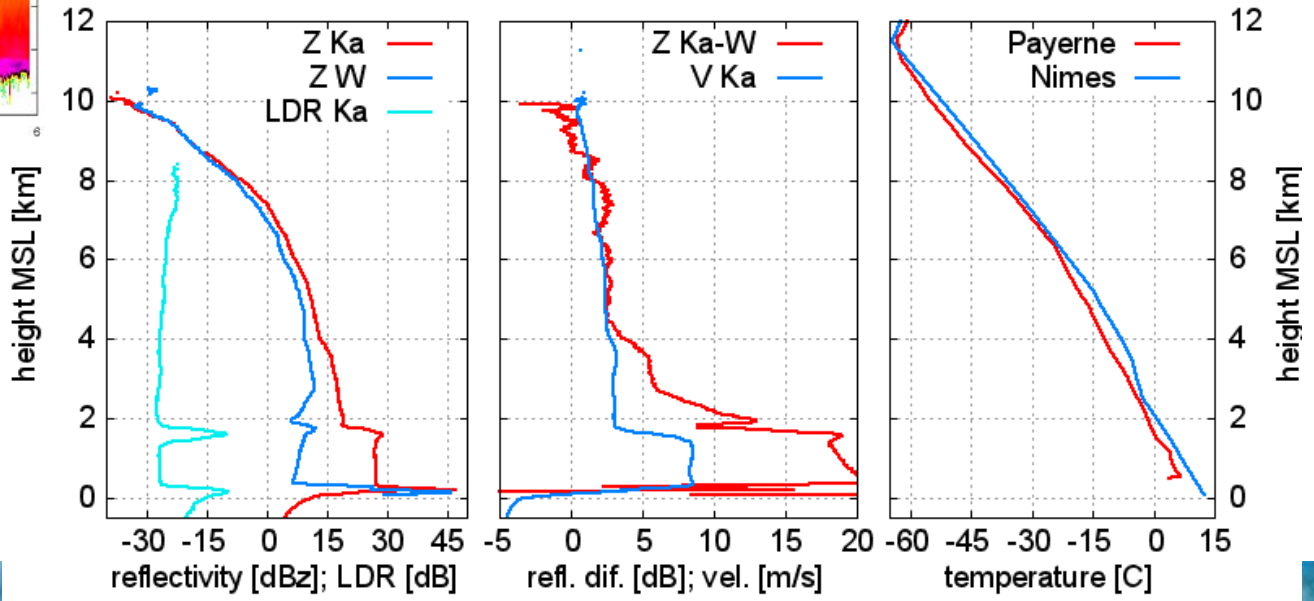
HALO Cloud Radar (Ka-band) – French RASTA (W-band)

3.70 E – 3.85 E



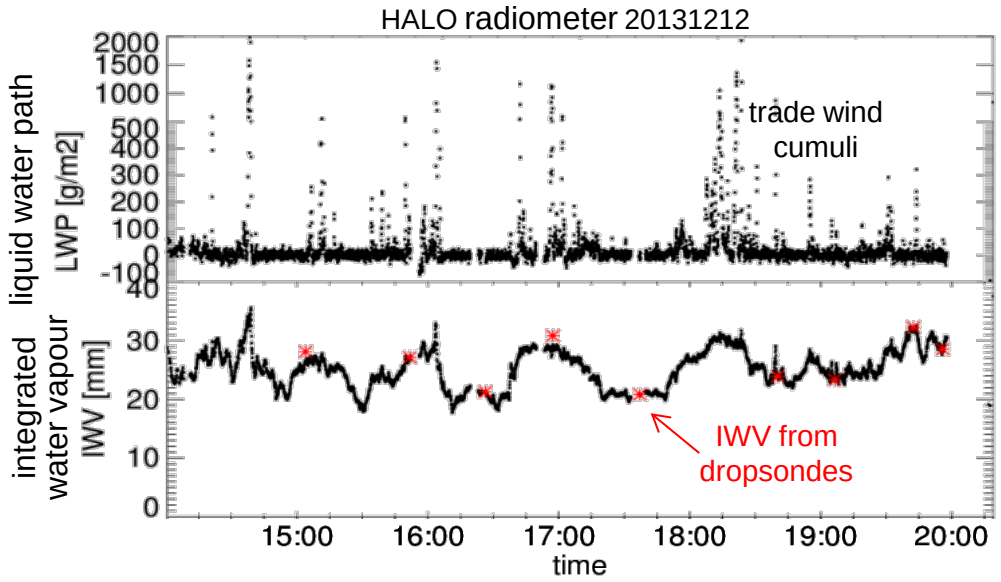


4.70 E – 4.85 E



Synergy of Radar, Lidar, and Radiometer

- Cloud phase:
  - Ice clouds, water clouds, super-cooled water clouds
- Cloud properties
  - IWC, LWC, eff. radius, … in regions with overlap of radar and lidar, and regions with radar or lidar only
  - vertical motion
    separation of vertical motion of air and fall velocity of particles
    feasible after phase classification and estimation of particle properties
- Integrated properties
  liquid water path, ice water path, integrated water vapour from microwave radiometers vs. intrinsic values from active instruments



Summary and Outlook

- Co-ordinated flight provides unique case of dual-frequency observations of clouds and precipitation

- HALO Microwave Package:
  - combination of active and passive remote sensing
  - still in the learning phase of the HALO instruments

- Ongoing research within NARVAL data-set
  - radar calibration, Cloudsat and Calipso intercomparison
  - passive microwave retrievals
  - radar – radiometer – lidar synergy
  - …

- NARVAL-2 to Barbados (summer 2016)
  NAWDEX from Iceland (fall 2016)